Welcome

*Dale Desrochers & Colin McGregor, DFO; Jason Hwang, PSF.*

DFO welcomed everyone, noting how the Department’s new Pacific Salmon Strategy Initiative (PSSI) relates to this workshop. Particularly relevant is DFO’s new Centre of Expertise, which seeks to expand DFO capacity to support restoration with more staff to support projects, more science and more engagement, including workshops like this.

PSF added that the purpose of this webinar is to support knowledge exchange on restoration. While not intended to be prescriptive, the focus will be on exploring the “Stage Zero” approach to restoration.

Co-hosts briefly reviewed the day’s agenda, inviting the over 300 virtual participants to submit questions via Slido. The entire session will be recorded and there will also be a workshop report.

Stage Zero River Restoration : Background, Theory & Practices

*Presenter: Colin Thorne, University of Nottingham & Wolf Water Resources, Inc.*

Key points in this presentation included (See PPT for more details):

* Presentation overview.
* Background: The strJanieam evolution model and anabranching rivers in nature:
	+ 1984 book by Schumm, Harvey & Watson: “Incised Channels - Morphology, Dynamics and Control” explored a 5-phase stream channel evolution model as a template for understanding the sequence of channel changes that often follow disturbances in nature.
	+ Subsequent work challenged the idea of single-channel streams as the original state. In 2008, Walter & Merritts noted that “before European settlement, the streams were small, anabranching channels within extensive, vegetated, wetlands.”
	+ Further work found examples of this undisturbed anabranching pattern around the world.
	+ Historical evidence references even the mighty Rhine River in Europe as previously consisting of “an immense network of interconnected streams, coves and marshy hollows,” which engineers like Johan Gottfried Tulla sought to “tame” to a single riverbed.
	+ Since 2000, work in Europe and the US has challenged the idea of single-thread, meandering as a natural, ubiquitous, pre-disturbance condition
	+ Cluer and Thorne re-visited the 5-stage channel evolution model in a new paper, adding Stage Zero to describe this precursor, multithread stage, and describing stream evolution as a cyclical rather than linear process, in which systems can skip or repeat parts of the cycle, evolving naturally or via engineering intervention.
	+ Intervention that arrests degradation (i.e. stream banks become un-erodable) leads to dead “Zombie” streams that stop evolving.
	+ Work in the Mississippi showed that without such intervention, streams could continue to evolve and reach quasi equilibrium (Stage 8,) with anastomosing, wet woodlands and grassy wetlands.
	+ Further work by Cluer examining the hydrological, morphological and ecological benefits of different stages showed a distinct difference between Stages 2-5 (poorer values) and the other stages (0, 1, 6-8), which were considerably richer.
	+ The target of restoration work should therefore seek to achieve the latter states.
* Theory: bankfull flow in transport and response reache
	+ Bankfull stage and discharge are key restoration design factors.
	+ Bankfull flow curves: Bankfull discharge = return period of around 1.5 years.
	+ Miller (1990) distinguished between 3 distinct zones over the length of rivers:
		- Zone 1 - Headwaters (source of sediment)
		- Zone 2 - Transfer (sediment transport) and
		- Zone 3 - Depositional (response)
	+ Hey (1970s) wrote about upstream and downstream mechanisms governing sedimentation and how those affect stream evolution, especially in earlier stages.
	+ Graphing discharge rates, frequency, inputs and outputs: lower flows are responsible for the most deposition; higher flows are responsible for most transport.
* Theory: Valley confinement
	+ Work by Schumm, Rosgen, Brierley & Fryirs (1985 - 2013): discussed valley confinement states: e.g. confined, partly-confined and laterally unconfined, with anabranched or anastomose channels found in the latter — i.e. wide open alluvial plains/fans.
	+ Valley confinement is a primary control on many fluvial geomorphic processes that occur on/along valley bottoms. The downstream sequence of valley settings is a key control on longitudinal patterns of hydrology and sediment flux and dictates the pattern of river types.
	+ Floodplain channels may be seen as ribbons; but Mark Beardsley’s work described a pattern that more closely resembles beads on a string.
* Theory: Stable channels:

	+ Lanes Balance — the idea that sediment size and stream slope govern stability by shaping the opposing forces of incision or aggradation — was used for many years, but…
	+ There are different potentially stable channel forms — not just the single thread meandering channel. A single straight channel can meet the criteria for dynamic stability; so can anastomosing or braided (if slope is steeper).
	+ Copeland Stable Channel Design Method: US Army Corps of Engineers formula showing that stability/equilibrium can be maintained if width increases with slope.
	+ What’s different between confined and unconfined systems is biology — with biological benefits increasing as you move from single straight channel to anastomosed.
		- And you can achieve this change through the energy of biology alone — e.g. beavers.
	+ Triangle model showing the relative influence of geology, hydrology and biology, with anastomosed systems reflecting peak influence of biology on stream processes, forms and functions.
	+ Cumberland plateau example: At the landscape scale, biological energy dwarfs geophysical energy by six orders of magnitude. Biology is by far the major influence on channel forms. So give biology a chance to do its work on the landscape.
* Thorne & Castro: 2019 Summary of Stage Zero definition and attributes.
* List of references.

The Long Road to Stage 0

*Presenter: Jeannine Castro, US F&WS*

Key points in this presentation included (See PPT for more details):

* Overview: this presentation looks at how practice and theory came together. The importance of this lies in how it affects habitat/fisheries recovery.
* Recap: Cluer and Thorne’s 2013 work introducing Stage 0 and highlighting the benefits of anastomosing systems.
* The focus of early channel restoration work in the 1980s, prior to this stream evolution model, was on holding systems in Stage 3 -4, which is the “ugly” part of the stream evolution model.
* In the 1990s, channel-focussed restoration involved starting to place large wood, etc to restore complexity in streams.
	+ What was wrong: Using logs to slow erosion halted the evolutionary process and kept the system in a stage that does not support much habitat.
* In the 2000s, we began working more at the reach scale (emphasis on Stages 5-6), which was an improvement but still did not meet the potential.
* At that time, we started talking more about meadows, flood plain value and how to reconnect them. Stream channels had been designed to be just transport channels, so we did not get wet meadows/wetlands.
	+ The US Forest Service was willing to experiment with new approaches, such as downsizing channels (theory that a bankfull channel was too big).
	+ “Happy accident” in Karnowsky Creek (2002-2006 project) tributary, when a flood event filled in the new channel and beyond. It was initially seen as a failure until the fish biologists found it had provided fantastic new habitat. So they left it and it soon evolved into a Stage Zero anabranching stream.
* The transition that happened from 2004 to the present — pre- and post- Cluer and Thorne — took many small steps and involved trialing many small projects.
	+ Fivemile Bell started as a single-thread transport channel, but agreement was secured to try simply eliminating the channel. It soon evolved to Stage Zero, with ongoing monitoring and learning.
	+ This work culminated in a 2018 paper on a process-based approach to restoring depositional river valleys to Stage 0. This built on the 2013 Cluer and Thorne paper — the important thing was the coming together/ synergy of research and practice.
* Why Stage Zero? In talking to landowners and interest groups, Stage Zero may not be the right term. It doesn’t have to be multiple channels, but it needs wetland plants, and the water table needs to be at or near the surface, with a depositional environment where material is building up. You can call it Stage Zero or a connected floodplain system or a river-wetland corridor.
* Aerial imagery examples showing contemporary remnants of Stage 0. People got rid of them to make way for agriculture in many places, but you can still find them.
* References: Stage Zero Information Hub: [stagezeroriverrestoration.com](http://stagezeroriverrestoration.com)
* Are we there yet? We will probably never be there, but we need to keep searching and improving.
* Q/A: Will discuss later was specifically changed in the Fivemile Bell project — how it changed from single thread to multiple channels and what we learned from the shifting approach.

Identifying Depositional Valley Types

*Presenter: Paul Powers, USDA Forest Service*

Key points in this presentation included (See PPT for more details):

* Opening comments: A key part of our learning has come from sharing our projects — not just the successes but the unexpected results and happy accidents.
	+ How we are evaluating landscapes now has shifted from channel-centric to using “valley goggles” and working with valley-scale processes.
	+ Previously, it was about trying to stop bank erosion, but now we are taking a vastly different approach
* Valley confinement algorithm (VCA): used to map depositional as opposed to non-depositional valley types.
* Beechie and Imaki (2014) paper analyzed and defined the characteristics of confined/straight, meandering, anabranching and braided channel patterns.
* Taking a closer look at details of the valley context of a project will help to show why it is degraded and how to restore it.
	+ Start by looking at gradient and gradient changes.
	+ Example 1: Desolation: Look at both the stream and its surroundings, including how a former glacier and its remnants affect it. Large glacial particles create geomorphic control, which is a critical factor to consider.
		- In this case, why was it no longer controlling form? Why was the stream acting as a transport channel in a depositional valley? Why was the channel not at the lowest valley elevation?
		- Further investigation suggested that the stream had been channelized and other flow paths blocked during road construction
		- So the project work sought to reverse that intervention, by removing the berm and raising the water level back to where it would naturally have been in that section.
	+ Example 2: Chihuahua: Detailed analysis of the valley context showed how glacial history affected geomorphic controls that had confined that section of the river to one side of the valley..
	+ Example 3: Aller River, Somerset, UK: Was the context for this project a depositional valley?
		- There was a geomorphic control further downstream. It’s a broad valley, with long-term disturbance. The river was not at the lowest part of the valley.
		- Further analysis suggested it had been reduced to a single channel historically to facilitate road building and free up land for agriculture.
		- Quote: “Anthropocene rivers are largely imprisoned in the banks of their history.” - Brown et al, 2018.
		- The goals of restoring the floodplain to boost biodiversity and improve flood control were enthusiastically supported by local interests who were well aware of climate change risks and the value of using wetlands to store water and reduce flooding.
		- As a result of this successful “reset” project, the Aller River is now occupying the floodplain of its tributary.

Q&A Discussion

* Q: A striking concept from all three talks is this rejection of key ideas, such as that the river only needs one channel, or that the goal of restoration is to return it to what it was before degradation, instead of Stage 0 and being willing to experiment. How do you respond to that?
	+ Colin: There’s a danger in yearning for the rivers of the past, instead of looking to the rivers of the future. The idea of restoring to Stage 0 is not about restoring rivers that no longer exist; it’s a valley floor reset, though it doesn’t always have to be that extreme. We’re not going back but we’re going back to the future and we don’t expect the river to stay where it is when we restore — we expect it to continue evolving. Natural channels evolve. So the restored river must be able to adapt to novel future changes that we can’t predict. It’s like a “CTR ALT DEL” that clears out all the past changes to set the river up to be resilient in a very uncertain future. Remove the constraints and redundant infrastructure and trust natural processes to make the river the best it can be in the face of future changes, instead of trying to impose a specific form, when we can’t know what the appropriate design would be.
	+ Dale: So we need to communicate with the public about the dynamic nature of rivers and the need to allow them the time and space that they want to be.
	+ Rivers will be the balance of the forces that act on them.
	+ Paul: Private landowners often want the river to go back to where it was convenient, instead of letting the river be a river at the appropriate scale. So you need to consider the benefits of doing that and look at long-term as well as short term needs.
	+ Janine: From a fisheries perspective, if we think of rivers as linear features, they do not offer enough habitat for salmon recovery. We also need connected flood plains for fish habitat. We don’t need them everywhere but we need enough to sustain fisheries and aquatic ecosystems.
* Q: How do you target specific restoration sites, given that they run through land owned by different interests with different objectives?
	+ Jeanine: We don’t need connected flood plains everywhere, so we are trying to be opportunistic, focussing on federal or state land or easements. We are not trying to get landowners to give up a bunch of their land. It’s important to choose willing partners and over time more people will come on board.
	+ Paul: It’s not an accident that many projects have been on federal land. But neighbouring landowners have also asked if we can do the same thing on their land.
	+ Colin: We worked with a sheep farmers’ valley cooperative in Wales who recognized that the quality of their farms had degraded over the years and wanted to leave a better legacy. They recognized that they had over-drained and dried out their flood plains and appreciated the value of the ecosystem services. So farmers don’t want the land re-wilded but they do want it to be as productive as they remember it used to be. These changes support huge productivity and put significant energy back. So often it’s not a conflict of interest but a common goal —- restoring it to what it was before we took out more than nature can put back. Older landowners can recall what it was like before and understand that.
* Q: Sequencing: How do you minimize impacts to migrating fish during restoration?
	+ Jeanine: This is one of the biggest concerns we hear from fisheries biologists. We did pit tagging and had contingency plans in case we lost fish passage. But from experience we’ve seen it’s not the issue we thought it might be.
	+ Paul: A common concern for projects with anadromous fish is that multiple channels won’t provide sufficient depth for passage. But often the barrier for spawning habitat is more about velocity of water and we find mean depths higher and velocity lower after this work. It’s important to remember that species like chinook have been evolving with disturbance and they thrive on it. For chinook, also, the challenge is often more about the loss of rearing habitats and this creates better rearing habitat.
* Q: A lot of BC habitat is stuck in Stages 3-4 due to agriculture and development. How to address that?
	+ Colin: If you can’t get the full flood plain back, work with what you’ve got. It doesn’t need to be valley wall to valley wall. There are good projects in Portland and Northern Ireland in urban landscapes. It’s more like a Stage 8 project as the terrace is no longer available.
	+ Jeanine: How much space do we need is a huge question. When the flood plain gets to around 10 times channel width, it starts to support multiple channels. We want to avoid channels that flip it to a transport or depositional section, so we want to ensure it can sustain the flood plain. If you don’t have the space, don’t try to do a project.
	+ Paul: We are working on some Stage 8 projects on the McKenzie River.
* Q: With eroding banks, if you can’t restore natural processes, do you ever just fix that?
	+ Paul: We used to think of that just as sediments polluting the water but we no longer think of it like that. We now think of rivers’ effective movement of sediment. So now we would re-establish geomorphic controls — use the bulldozers to raise it back. Then upriver you start to backwater. It’s better to carry suspended sediments, and obstructions cause sediments to fall out over the rough elements.
	+ Jeanine: The first part of my career focus was on bank stabilization. You can look downstream and tell them it will only erode another 20 feet or so. So you look at the stream evolution model and maybe put the stabilization further out, not at the existing banks.
	+ Colin: Decisions must be risk based. There’s a big difference between whether it’s a nuclear plant or soybean field. But stabilizing banks can also cause new risks — e.g. it led to the failure of a bridge downstream.
* Q: With atmospheric rivers, forest fires, flood risks, and rapidly changing conditions, what should be thinking about when trying to advance connectivity?
	+ Jeanine: One of the big surprises with Stage 0 is these projects providing wildfire refuges, e.g. tree roots don’t burn.
	+ Colin: We need to be very clear in distinguishing flood vulnerable from flood risk. Flood protection is appropriate for places where homes and businesses exist but that’s a small portion of the watershed. Wetland areas are very suitable elsewhere and are not getting flooded enough. We can expect the need for more flood management and this can help to take the pressure off flood-vulnerable areas.
	+ Paul: This work turns a lot of what we used to think on its head. Things that are a threat with single channel are less of a threat with these systems — and in fact fires and floods add new benefits to these areas.

Low-tech Approaches to Project Design & Implementation

*Presenter: Jared McKee, US F&WS*

Key points in this presentation included (See PPT for more details):

* Restoration science, like early attempts at flight, was all about how to achieve stability.
	+ The goal now is to Refocus restoration from reconstructing channel forms to promoting a more robust and dynamic stream/floodplain environment.
* Presentation will cover background and scientific basis, the 4 key criteria, putting them to work and key take-aways.
* Why this shift? Stream restoration was not meeting ecological standards, process-based principles or providing anticipated biological benefits.
	+ Example of failure/blowout of restoration project.
* Scientific basis: This work has benefited from many papers that informed an improved design approach — e.g. using beavers or “beaver analogues.”
	+ 3 pillars for an ecological process-based river restoration framework: ecological engineering, applied geomorphic analysis and riverine ecosystem theory.
	+ Underlying principles (AD Bradshaw, 1996): why helping a river to help itself is an appealing strategy.
	+ Ecological standards (Palmer et al, 2005): 5 standards for ecologically successful restoration.
	+ Process-based principles (Beechie et al, 2010): 4 process-based principles for restoring river ecosystems.
	+ Cluer & Thorne 2013, Pollock et al 2014.
	+ All this led to the paper by Ciotti, McKee et al: “Design Criteria for Process-Based Restoration of Fluvial Systems.”
* Space criterion: Does it restore the spatial extent of fluvial processes and connectivity lost due to human alterations or just work within current confined space?
	+ Key factors that lead to degradation and disconnection.
	+ Key to success for process-based restoration is allowing sufficient space for natural fluvial processes to occur.
		- Key benefits of doing this.
	+ Sample of programs around the world that emphasize space is essential.
	+ Comparison of form based and process based approaches.
	+ How form-based objectives and practices are translated in a process-based approach.
	+ Space and connectivity: Allowing more space for fluvial dynamics capitalizes on the ecosystem service of self-system recovery and restores habitat lost through anthropogenic actiivity,
	+ Formula: Final process space must be greater than initial process space.
	+ Space criterion: Doty Ravine example
	+ Space and source problems: common source problems (including biological impediments and impediments to natural biological forces necessary for recovery)
	+ Delineation of fluvial process space: it’s less about channel form and more about gaining space and connectivity. Even partial occupation of the historic process space can yield ecological benefits.
	+ Doty Ravine: before and after.
* Energy criterion: project actions capitalize on natural energy within the system to do the work of restoration and minimize the use of external mechanical energy.
	+ Parallel of green architectural that capitalizes on natural heating and cooling.
	+ Shift from geomorphic to biological: consider the river’s energy for transport, solar energy for vegetative growth and metabolic energy from animals, e.g. beavers.
	+ Creatively maximize the system’s potential energy to meet restoration objectives while avoiding use of extrinsic energy (e.g. heavy equipment) — this is a major change from form-based restoration.
	+ Understand when, where and how energy in the system is created, stored, moved and used. Understand that it will take time: You’re working with the stream to establish a sustainable form
	+ Fluvial energy can be used to connect latitudinal and longitudinally. Look for blockages or modified flow paths
	+ Process-based approach also harnesses biological energy, especially in alluvial stream reaches where vegetation tends to shape and direct the geomorphic and hydrologic processes.
	+ Restoration actions that encourage recolonization by “ecosystem engineers” like beavers, wolves, freshwater mussels and willows can make use of their biological energy to increase habitat diversity and resilience to maximize the benefits of restoration.
	+ Biological and hydrological energy direct the biophysical recovery of the ecosystem — and underscore the importance of thinking beyond traditional hydraulic energy and geomorphic form considerations.
	+ Other important energy sources: wildfires and landslides; capitalize on major events that deliver large pulses of sediment and wood — potential disaster becomes a restoration action.
	+ Energy design criterion discourages use of heavy equipment, but it may be necessary to modify infrastructure. Reserving heavy equipment mainly for infrastructure removal minimizes disturbance and carbon footprint and can also facilitate permitting.
* Materials criterion: projects use locally sourced, geomorphically appropriate material and avoid overly stabilizing elements.
	+ Ensure largely immobile structures won’t be built where those would not naturally occur and where they may affect natural recovery processes.
	+ In-stream structures may be built from wood, sod and in some cases, rock.
	+ Design Manual: Low-Tech Process-Based Restoration of Riverscapes
	+ Materials are strategically placed to accelerate channel evolution from single to multi-thread forms.
	+ Structures are evaluated based on the process they induce, not their permanence
	+ This approach reduces design and construction costs.
	+ Low-tech process-based restoration — e.g. relying on beaver dam analogs (BDAs) and hand-placed wood jams — are low cost, require minimal energy input, have minimal construction footprints and allow for adaptive control of flow energy and sediment over time.
* Time criterion: Habitat objectives are achieved over time via restored geomorphic and biologic processes.
	+ This challenges the assumption about instant, once-and-done solutions.
	+ Minimally intrusive but incremental restoration over time promotes understanding of the system and help identify actions most likely to restore natural fluvial and biological processes.
	+ Forces the designer to anticipate how the project area will likely change over time ue to disturbance and ecosystem changes.
	+ It may require a decade or more to evaluate project success but measurable improvements can be seen sooner.
	+ Time frame to achieve success varies. Factors include the extent to which you address source problems, flows and disturbance events.
	+ Monitoring is important to assess whether it’s on a recovery trajectory.
	+ Timeframes for recovery allow time for the likely occurrence of flood, followed by periods of vegetative growth and other biological activity
	+ Floods should generate measurable improvements. If not, review source problems — opportunity for adaptive management.
* How to implement this approach:
	+ Get to know your catchment: Review available data to determine fluvial process space, including GIS, historical data, land ownership and use, geology, aerial photos, catchment hydrology, other energy sources, etc to decide where to spend your available time and resources.
	+ Draw your stream evolution corridor (SEC), main channels and historic channels, alluvial fans, infrastructure. Develop communication tools to explain the project to partners.
	+ Site inventory: what’s there, how to nudge it to build on what’s already working, what’s missing.
	+ Shift from one-off restoration to stewardship mindset.
	+ Set explicit goals for establishing a restoration trajectory.
	+ Track changes, evaluate past action and adapt future actions.

Q&A Discussion

* Q: What do you say to those who see beaver dams as barriers to fish passage?
	+ Jared: Extensive research shows they bring extensive benefits and that fish get around these things, including juveniles. They have co-evolved over millions of years. Quote: “Beavers taught salmon to jump.”
* Q: Several questions talk about integrating traditional/indigenous knowledge and reconciliation in this work.
	+ Jared: I learned a lot working with US tribes and they really appreciated the approach of working with nature, in a non-heavy handed way. They see the ecosystem as part of the family. It’s important to try to keep the heavy machinery to only those spaces that were created by heavy machinery. Another thing is working with native plants. It’s important to listen and learn how they see the area and want to see it restored.
	+ Janine: US tribes are key partners in many of our projects, especially with restoration of lamprey habitat, so there is a lot of synergy with our work.
	+ Colin: In a project to reconnect a tributary on the Columbia, the beavers came in and replaced our analogue dams with their own dams, except in better locations. We also saw the re-emerence of thousands of native wapato bulbs once we re-established the wetlands. They had been there all along, just buried, and it’s a nice metaphor for the opportunity for the re-emergence of indigenous people who have been buried under western culture.
* Q: Where should beaver dam analogues be located?
	+ Two great resources are the Low-tech manual and Janine’s manual, but typical locations include confluences, bifurcations and riffles.

Q: A number of questions relating to DFO plans for such work will be compiled and addressed at a later forum.

Case Studies: Overview - Completed Stage 0 Projects

*Presenter: Colin Thorne*

Key points in this presentation included (See PPT for more details):

* 2-3 dozen US Forestry Service Stage 0 projects have been completed across Oregon to date.
	+ Stage 0 projects are not recommended for everywhere. Also don’t advise people to dive in the deep end with risky, high profile projects: USFS started with small projects in upstream basins.
* Examples:
	+ Dick Creek, Ochoco Nation Forest: 4 hectares, 2013: Instead of trying to hold it in Stage 3 (Zombie state), they filled in the channel to restore it to Stage 0. After 2 years, the system was rehydrated, with the natural biology unleashed.
	+ Wooley Creek S. Oregon: 8 hectares, 2016: Filled in the old channel and saw significant improvement just 1 year later.
	+ Lost Creek - 2012: incised channel had dried out the aquifer, converting a meadow to dry uplands. Filled the incised channel with 6,000 cubic metres of fill) and restored the aquifer and wet meadowlands.
	+ Fivemile Creek & Bell tributary: The creek had been pushed to the valley edge to create pasture, which was drying out and losing its fertility, so this was an opportunity to restore bottom wetland (45 hectares) in phases between 2011 - 2018. The result was slower flows and abundant new juvenile coho salmon refugia. Initial work included scratching pilot guides for secondary channels in the valley floor. They didn’t last, but natural processes achieved the same result elsewhere without our help. The restoration work left rough features in place so we quickly got differentiation and the desired mosaic of habitats.
	+ Whychus Creek: 100 hectares, 2015: We are seeing vegetation, flow and biodiversity spring back within 2 years. When flooding came, there was no drama, as it spread out over the entire valley floor, creating lots of new habitat for lamprey, juvenile fish and amphibians. Groundwater recharged very quickly once we had eliminated the incised ditch. It refilling the alluvial (upper) aquifer, which is actually connected to the river.
	+ Stage 0 “poster child” — South fork McKenzie River, Oregon: Phased construction, starting in 2018 and 2019 (2 further stages to be completed). The upstream dam releases periodic flushing flows, along with summer releases to regulate water temperatures, so the dam was actually an asset to restoration (more knobs for us to use). The project involved de-watering the main channel, salvaging resident fish and wildlife, and then reconnecting the historic blocked channels using heavy machinery. Fill from the berm removal was used to fill in the main channel. This was very large scale and something you would only attempt when you know your trade. Large woody pieces were added to prevent re-incising. The aquifer filled in just a few days — so they needed to move out the heavy equipment quickly. The result was lots of new channels, which means lots of rich edges, and significantly increased total wetland area.
		- Video: river before (firehose) and after: that’s what happens when you spread the flow over the entire valley floor. Nutrients are being cycled and the aquifer recharged, with beavers back and working in the side channels.
* A legitimate concern (along with fish passage) is that water temperatures will increase. But we’ve found this to be less serious than expected because you see enormous temperature variation, with lots of cold water refuges. The aquifer is also exchanging cooler water with the river — underground is a far better way to cool water than shading.
* Outcomes: Fully connected, fully hydrated systems provide habitat for everyone, from microbes to bears.
	+ The McKenzie project saw a 5-fold increase in fish density (so 30 times more when you consider the additional habitat area as well).
	+ The restored section now has 80 redds per kilometre — the highest concentration in the McKenzie Basin. So you can make a difference for salmon at the population level by restoring just 20% of the basin. The redds are mainly in the *disturbed* areas. We should not be surprised by that, because anadromous fish are like weeds — they have evolved with and are built for instability, not stability.

**Discussion**

* Q/A: Once the river’s energy was spread over the wider valley floor, velocity was not high enough to re-incise new channels. But you need to tie it to a natural geomorphic control like a glacial moraine or alluvial fan downstream to prevent that happening. We don’t see problems with re-incision as long as you fill the channel in completely and roughen it. You’re converting a single channel transport reach into a pre-disturbance condition (a natural depositional reach), so more flooding means more deposition, which is beneficial, instead of worrying that the floods will rip your work apart.

**Presentation, continued**

* + Mudpool Meadow, UK - National Trust Riverlands Project: We started small, creating a “leaky dam” or beaver dam analogue to slow the flow and retain water to re-hydrate headwater meadows. The project involved US/Brit learning exchange visits, which led to a decision to just fill in the ditches, creating a muddy mess that initially horrified the locals. But after a few years, we now have diverse habitat and fertile meadows. This restoration has also benefitted from bringing pigs in intermittently to create the desired disturbance.

Process-Based Restoration Applications USFWS

*Presenter: Damion Ciotti, US F&WS*

Key points in this presentation included (See PPT for more details):

* Process-based restoration (PBR) is about the science of how to get nature to do a bigger share of the restoration work for us. Such an approach allows us to scale up programs and do more for sensitive species.
* Case Study: Restoration project in California’s sierra foothills.
	+ We were initially invited to look at creek bank erosion due to cattle grazing, where they just wanted to stabilize the banks.
	+ We convinced them to stop killing/trapping beaver and allow beaver dams. Pretty quickly the river reconnected to the surrounding lands and they realized that bank erosion per se was not the problem.
* Setting the project goals: the end point is dynamic.
* What processes there are to restore and what metrics to measure: primary productivity, deposition and erosion, channel migration and anabranching.
* What is PBR? It involves addressing the source problems, including infrastructure and land management, looking at upstream problems and downstream-based controls.
	+ Idea of structurally-starved systems — once we address that, we start to see recovery happen, with riparian areas coming back.
	+ But it’s still a single-stream channel. Using low-tech PBR, with wood loading and beaver dam analogues (BDAs), we can get more recovery. Even adding a small amount of wood can make a big difference.
* There are useful manuals to guide the work, so find a site and start experimenting. We work with the dynamism in these systems, so each site will be different.
	+ We’re working in the context of the channel evolution model and looking for the low hanging fruit, like the beavers do, to find the ideal locations that will provide a lot of habitat change quickly.
	+ Working on channel recovery is often just about raising the water table to get more connectivity.
* Why the PBR approach? You enhance biological function and reduce disturbance with the low-tech approach. Secondary benefits include easier regulatory hurdles and reduced carbon footprint.
	+ Paper on design criteria for PBR (Ciotti et al, 2021): Speaks about defining quantitative metrics for what you’re going to do and how. This paper compiles what was already in the literature, highlighting the importance of open space and connectivity, energy, using natural site materials and working adaptively with nature over time.
	+ Setting goals in river restoration; looking at suitability and for opportunities where the river can heal itself.
* Opening lateral space: successes seen with semi-confined flood plains, especially where there was only one landowner. Livestock interests are generally easier to work with than more intensive agriculture.
	+ Longitudinal space: connectivity, road networks and geomorphic units.
* Energy: using natural energy to do the work of restoration (solar, flood energy, biological) and minimizing external mechanical energy.
* Materials: Use natural materials from the site or nearby that would otherwise be waste products. Don’t try to over-stabilize or unnaturally constrain channel migration.
* Time: Do it adaptively over time, as you learn how nature is working on your site.
* Once you connect incised channels to the flood plain, continue to spread the water out within the system.
* It’s not about the structure you’re building but the process you’re invoking. The goal is the process that arises from the structure.
* Getting nature to do the work means there is no blueprint up front and you need an adaptive approach
* Most projects require ongoing maintenance, whether PBR or form-based.
* Lessons learned from working with beavers — humans are really inefficient:
	+ Example of staged process to raise the water table in Year 1; then the beavers came in and gradually connected progressively more area.
	+ Channel filling is not aways necessary — beaver can do it.
	+ We were over-stabilizing areas that we didn’t need to.
* Building structures can be a good volunteer opportunity, but it’s a lot of hard work. We hired a regular crew to work on our sites for several weeks each year.
* Idea of reactivating flood plains without filling channels.
* Don’t just look for the deepest, but also the shallowest areas.
* Fix the lower valley control but don’t sweat most head cutting and bank erosion.
* Do the analysis to avoid costly mistakes — those include missing opportunities to get nature to do the work instead.
* Look at carbon emissions and sequestration.
* Tools and groups: Links to the California PBR Network and Riverscapes Consortium.
* Example of using LIDAR to identify hidden meadows.
* Modelling work for the Sprague River in Oregon:
	+ Bring in metrics for space, energy, materials and time.
	+ Identify existing connectivity, valley space available, area to re-wet, which areas have been disconnected by infrastructure or incision, where to place BDAs, priority infrastructure within disconnected areas.
	+ Prioritize what infrastructure to modify, and where to place PDAs.
* Research on benefits of beaver activity shows these include reducing forest fuels, making the landscape wetter and getting more fuel material into our streams.

Q&A Discussion

* Q: What about regulatory barriers to putting materials in streams?
	+ Engaging regulators has been critical to our work. We’ve been able to work through issues, but it required strong outreach.
* Q: Are there also examples of failure and what was learned from them?
	+ Having professionals who can look at each others’ projects and evaluate them critically is very important. Sometimes there are happy accidents; or we can learn from the unexpected if we give ourselves a chance.
	+ A common mistake is making our channels too big, due to fears about flooding and erosion. In the Wales example, that starved the downstream of sedimental and led to head cuts. Smaller channels will naturally enlarge but channels that are too big will take a long time to settle down.
* Q: Question about how the upstream dam in the example affected sedimentation and braided channels dewatering in summer.
	+ We used specific features at the edge of the valley that created local landslides, providing a gravel source, but we may still need to do some gravel projects in the future — no project is forever. These are not braided channels but rather anabranching or anastomose, which act as separate channels. They are not as dynamic as braided channels but have a recuperative power, so they tend to recover their form when disturbed.
	+ There have not been fish passage problems due to dewatering. We see more depths during summer low flows than before and the habitat is now very heavily used by adult salmon.
	+ The area is recharged in winter and flows very slowly in the summer.
* Q: Any recommendations for when you have to protect infrastructure? Can a PBR approach still be taken?
	+ We’ve done work on blue/green cities and infrastructure. Restoration strategies must be fitted to the anthromes in which they exist, but all the evidence is that the more nature, the healthier the human population will be. There is no one-size-fits-all but most cases are somewhere between very dense urban areas and total wilderness. You can get around the skinny water problem — for example, an award-winning greenway project in Belfast, which also provides flood protection. Residents love it. Other examples include the Fanno Creek restoration and Bethany Creek in Oregon.
* Q: How do put this to use? Is there a best practices handbook for BC stream keepers, who would have very diverse skill levels?
	+ Jeanine: There is no single guidebook. It’s important to also have a community of practitioners to train, evaluate and support practitioners. The more important piece is training, building community networks and getting out to observe projects first-hand.
	+ Colin has a nice website:
	+ River Restoration Northwest is an excellent conference.

Geomorphic Analysis & Design: British Columbia examples

*Presenter: Paul Powers*

Key points in this presentation included (See PPT/session recording for more details):

* The first presentation focussed on how to find appropriate valley types and break them up into different zones for restoration.
* This presentation explains how to look at multiple factors and available data sets to identify suitable sites, using British Columbia examples.
	+ Looking at REMs, elevation relevant to the valley profile to show fluvial process space in a valley.
	+ Explanation of how to build a valley cross-section model (using an application like AutoCAD).
	+ Once you build that, walk around the site and use field indicators to confirm if the banding is correct.
* Instead of just looking at the channel and how to improve it, we’re now looking at the entire valley and relic flood paths.
* We look at which features are natural that we will work with, and anthropogenic features that we want to remove.
	+ A valley “reset” largely focusses on addressing the anthropogenic features.
* The result provides a diversity of habitat to support salmon recovery (ideal habitat both for spawning and juvenile rearing).
* Bella Coola River example:
	+ Used LIDAR imagery; broke the valley into 5 segments.
	+ Segment 2: Establishing target elevation (geomorphic grade line).
	+ Compare/verify the results with a field visit.
	+ Look at cross-sections of the valley topography at different locations to identify where it’s already closest to the target elevation.
	+ Then assess key context/features: downstream control point, upstream sediment sources necessary for a successful project.
	+ With all this info (subject to site visit confirmation) it looks like you could do beaver-dam-like structures to create an anabranching segment in the upstream portion of Segment 2 of this valley.

Q&A Discussion

* Q: It seems counter-intuitive that restoration would start downstream instead of at the top.
	+ Paul: Many things about these projects are the opposite of how we used to think. We look at geomorphic history and how to use that to do the work. If you can re-establish the natural geomorphic control, you can start to charge the groundwater, and sediment deposition occurs upstream.
* Q: Would Stage 0 approach be suitable for other channel types?
	+ Colin: Before we thought of Stage 0, thee was a scheme in Scotland that was ahead of the curve. They were storing water upstream and using breaches to reactivate the floodplain that had been disconnected. It’s now fully reconnected, with rehydrated floodplains. Some people don’t like Stage 0 term, but you can call it something else.
* Q: How did you raise the elevation of the stream to reconnect it?
	+ Janine: We took the material we had removed elsewhere to completely fill that channel and stripped away the invasive grass that had been covering it. That uncovered a seed bank of native plants beneath which then flourished. It’s now completely flooded for months, providing great coho habitat.
	+ Paul: We had a “Happy accident.” We tried scratching new channels, which were lost immediately and the natural processes then made their own channels. So for the next phase, we just filled it in and left it.
* Q: So is this a unicorn or something we can replicate with reasonable frequency?
	+ Janine: It’s not a unicorn. It is possible in many of these low-gradient or coastal systems, in gravel or finer sediment systems.
* Q: What were the key assumptions/decision points for drawing the centre line?
	+ Paul: That’s not critical but the importance is understanding the upstream/downstream hinge points (so you need to know the broader context, downstream geomorphic control and tie your project to it). Sometimes it’s a geological feature or where a tributary joins.
* Q: What’s the typical strategy if the incision has been caused by climate change, logging etc.?
	+ Paul: Give the system space. Look at what the system was at the time of death. Our future will have a different climate and other new challenges, so make the system resilient to whatever challenges the future brings.
	+ In one example, there had been clearcuts and dams/sediment, then they removed the dams and the flows cut back through those sediments. If you can distribute flow impacts and sediments over the whole valley, that reduces incising.
	+ It’s about addressing root causes instead of working downstream and ignoring those.
	+ Colin: In one example, storm flows had been exacerbated due to development. We needed to address both. Try to reduce storm flows but also help the stream to adapt by giving it a blue/green corridor space to convey and store water and sediment, process contaminants and transport nutrients. We’re not going to go back to the days before Lewis and Clark, but we can give it the space to be the best stream it can be, which provides habitat and resilience — those two factors are interdependent. The more adaptive capacity, the better they can serve us in an uncertain future.
	+ Janine: Slides showing the Fivemile Bell example, where an adjacent creek was completely biologically controlled. Slides showed Fivemile Bell in the prior incised condition, right after intervention and with substantial improvement after a year, with lots of good habitat. Right after the intervention it was just a dirt surface and people were worried that it would all wash away but we knew that it’s a depositional environment, so it didn’t.

Closing Remarks

* Dale thanked everyone for the presentations and questions, noting that DFO is looking forward to the new Restoration Centre for Expertise providing future connections, training, guidance, technical advice and the support tools referenced.
* Jason thanked everyone, adding PSF will publish workshop proceedings, share the workshop recording and other materials. Questions not addressed today will be collected and PSF will work with DFO to see how they can follow this up.
* Dale thanked the DFO staff who arranged the presentations and Oh Boy Productions for the technical set up. Jason thanked participants, adding that PSF looks forward to the next instalment.

Additional Links

* YouTube video: How Fivemile-Bell restoration was implemented. <https://www.fs.usda.gov/detail/siuslaw/landmanagement/resourcemanagement/?cid=stelprdb5383646>
* Longer (1-hour) Video account: <https://www.youtube.com/watch?v=tj3IlX5E_g0>
* Trail Creek beaver ponds: GIF showing changes over 1 year following BDAs and a couple of beavers who showed up to help: <<https://www.dropbox.com/s/9xjm4sc3o35e19o/Trail%20Creek%20Beaver%20Ponds.mp4?dl=0>>.